Transport through low-dimensional superconductors

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INTRODUCTION

OVERALL AIM

- Develop a formalism to study transport through superconductors and encompasses thermal fluctuations
- Understand the Little-Parks effect in small-diameter cylinders
- Probe the magnetoresistance peak in thin film superconductors

FORMALISM

- We use the Meir-Wingreen formula for the current

$$J = \frac{\mathrm{i}e}{2h}\int \mathrm{d}\epsilon \Big[\mathrm{Tr}\left\{ \left(f_{\mathrm{L}}(\epsilon)\Gamma^{\mathrm{L}} - f_{\mathrm{R}}(\epsilon)\Gamma^{\mathrm{R}} \right) \times \left(G^{\mathrm{r}}_{\mathrm{e}\sigma} - G^{\mathrm{a}\sigma}_{\mathrm{e}} \right) \right\} + \mathrm{Tr}\left\{ (\Gamma^{\mathrm{L}} - \Gamma^{\mathrm{R}}) G^{<}_{\mathrm{e}\sigma} \right\} \Big]$$

- Describe the superconductor with the disordered negative-*U* Hubbard model
- Use a Monte Carlo summation over states to perform a thermal average

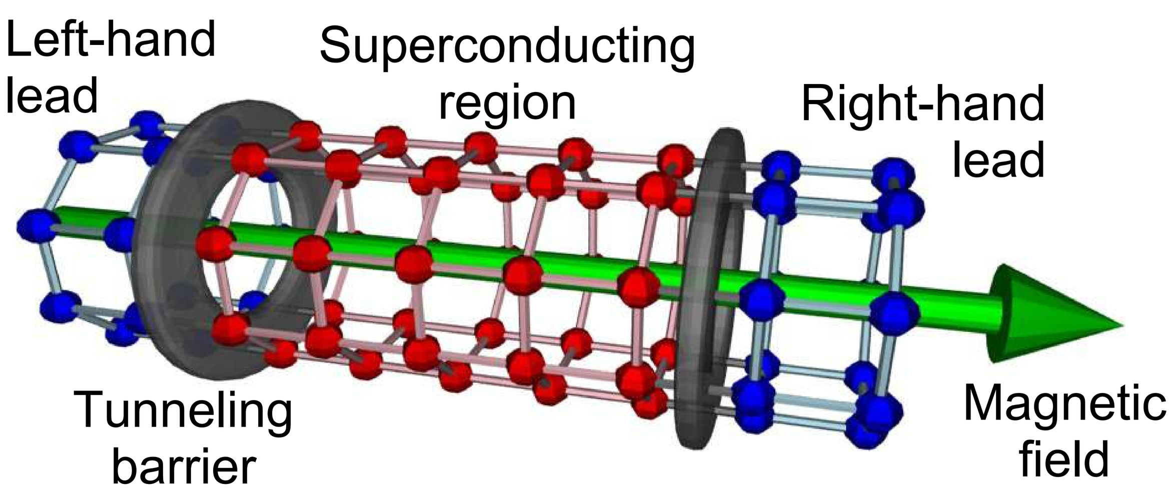
TESTING

Formalism verified against a series of well-established results:

1) Kosterlitz-Thouless transition
2) Nonlinear *IV* characteristic
3) Length dependence of conductivity
4) BTK transmission coefficient
5) Three-body interactions
6) Josephson tunneling
7) Little-Parks effect

LITTLE-PARKS

Fig. 1. Experimental setup



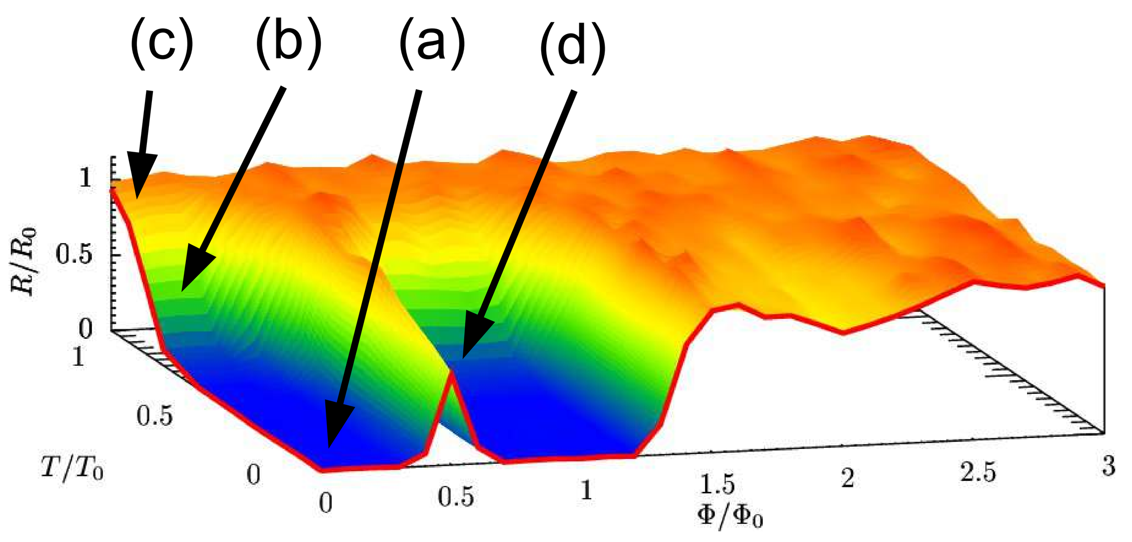
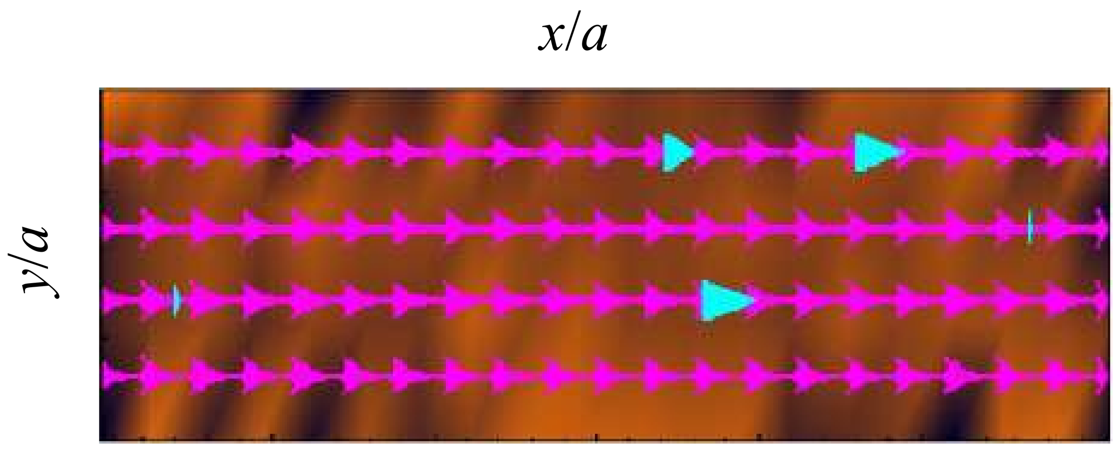
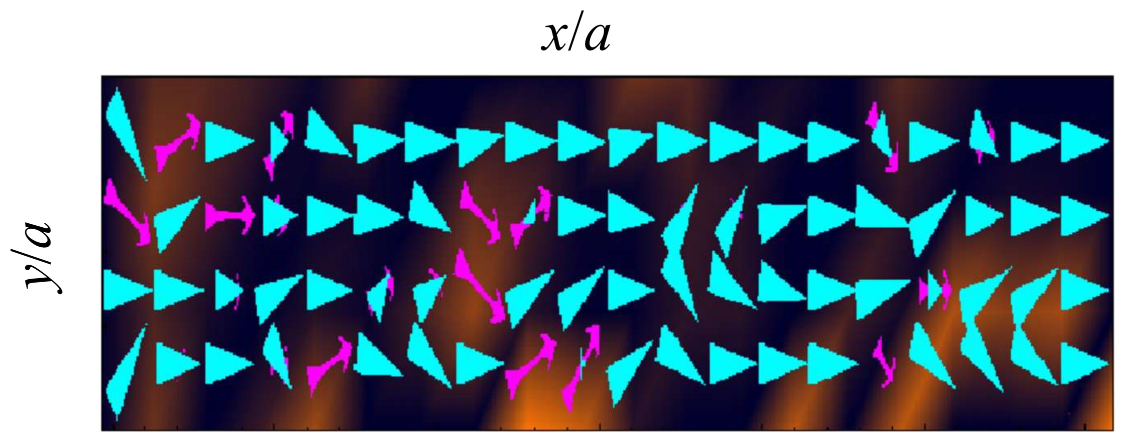


Fig. 2. Variation of resistance with magnetic field and temperature

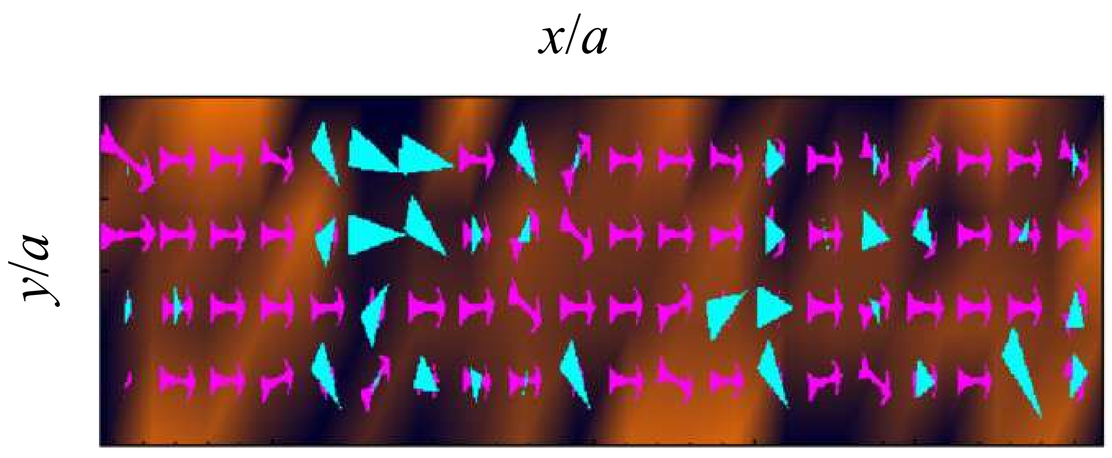
(a) Wire entirely superconducting with zero resistance



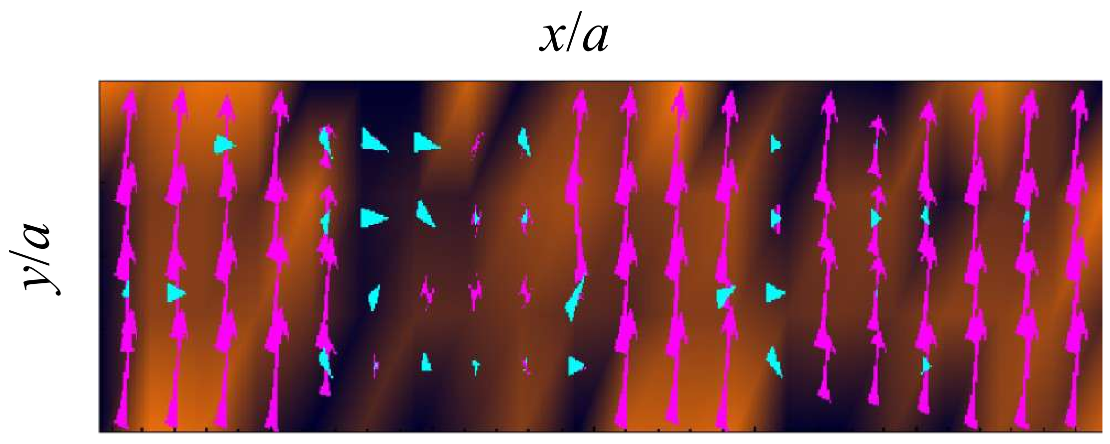
(c) Wire entirely normal with high resistance



(b) A normal state bisects the wire, driving up the resistance superlinearly



(d) When a half-flux quantum is threaded the wire is partially normal



MAGNETORESISTANCE PEAK

Fig. 3. Experimental setup

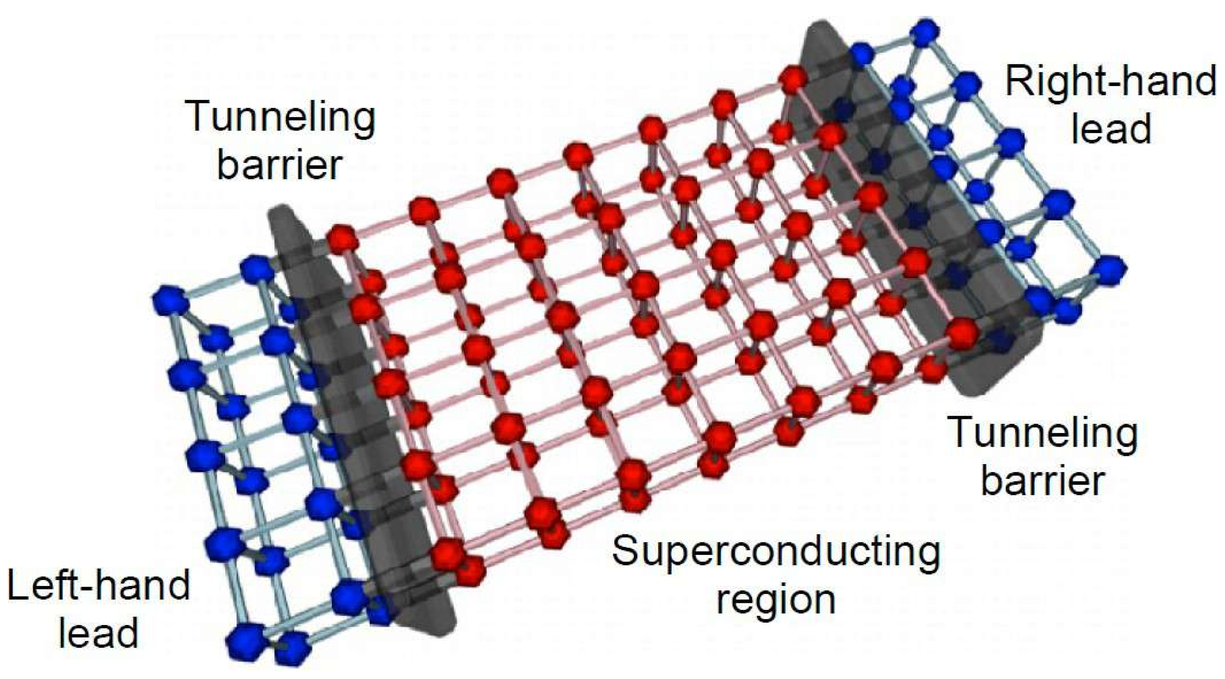
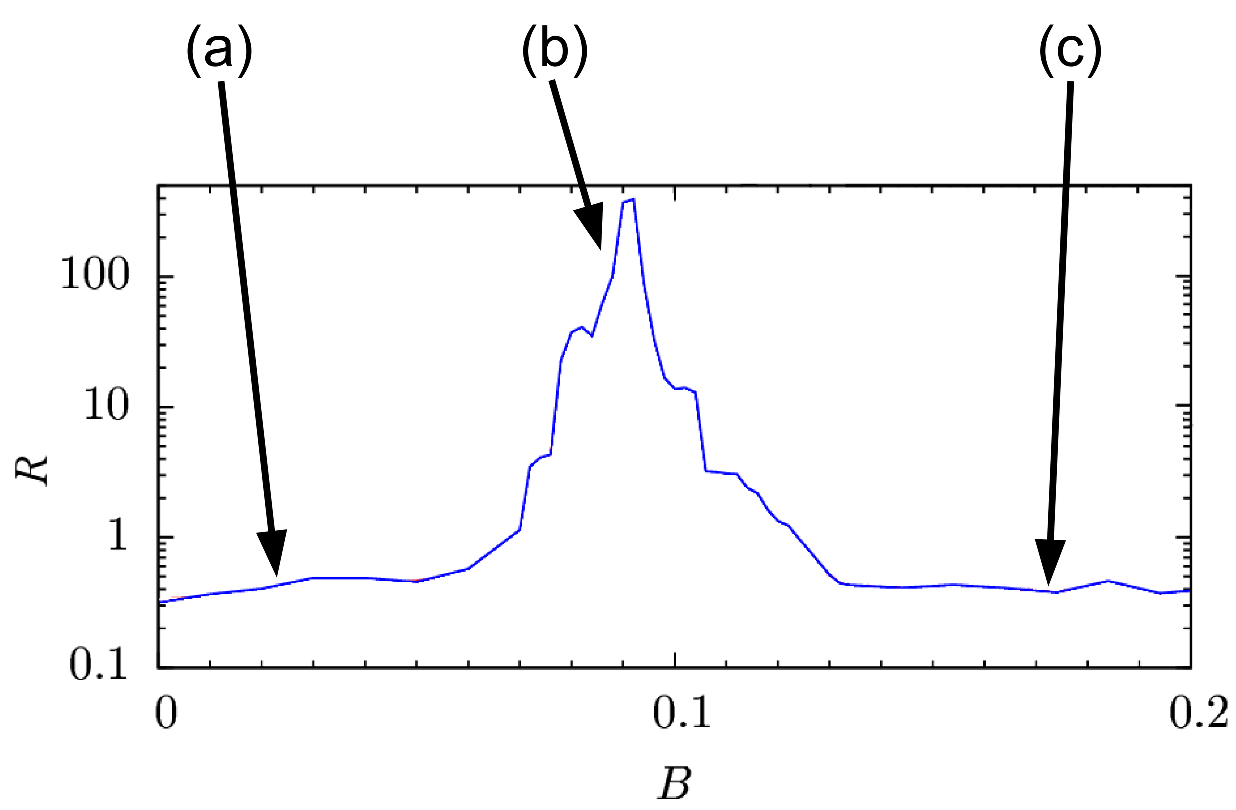
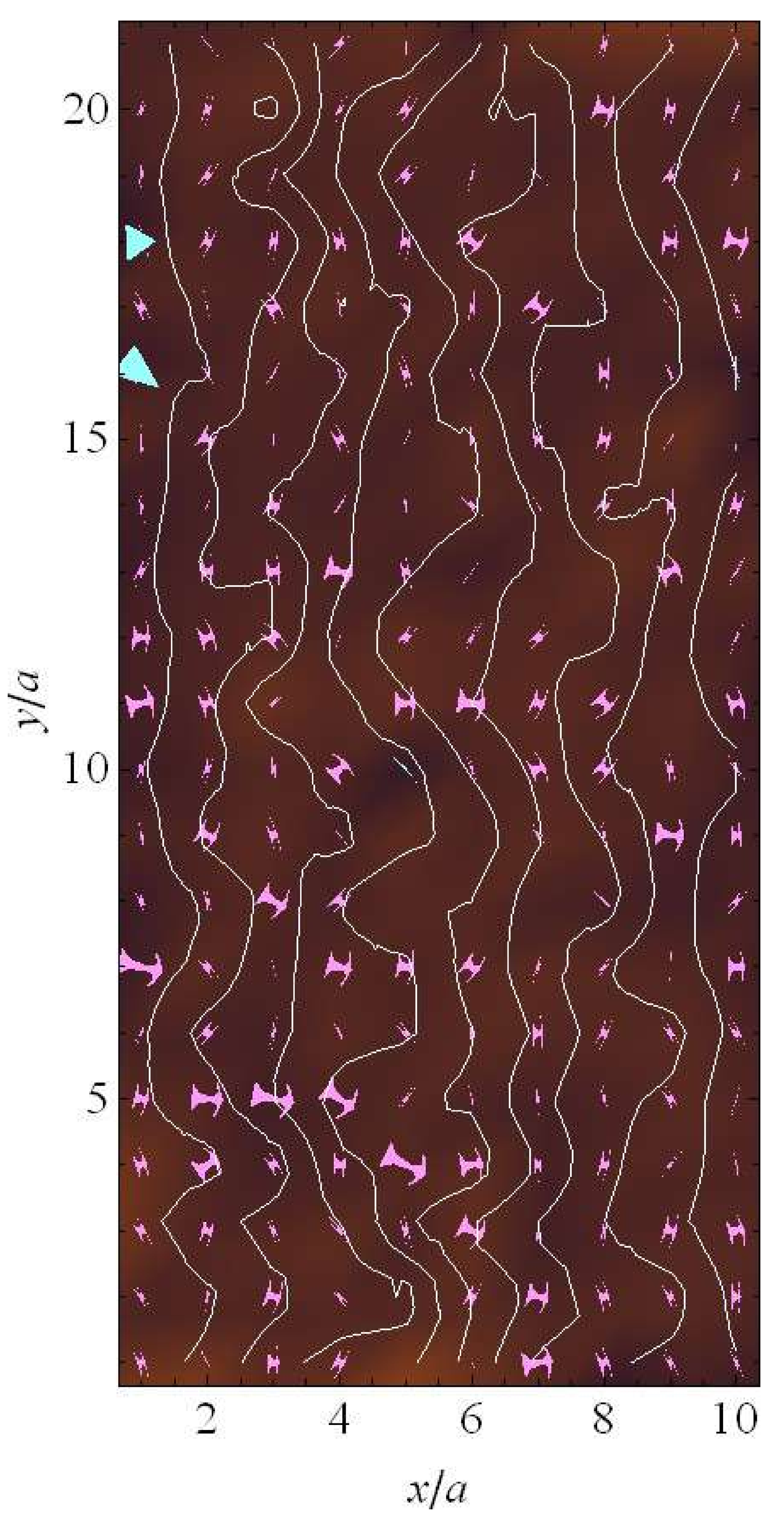


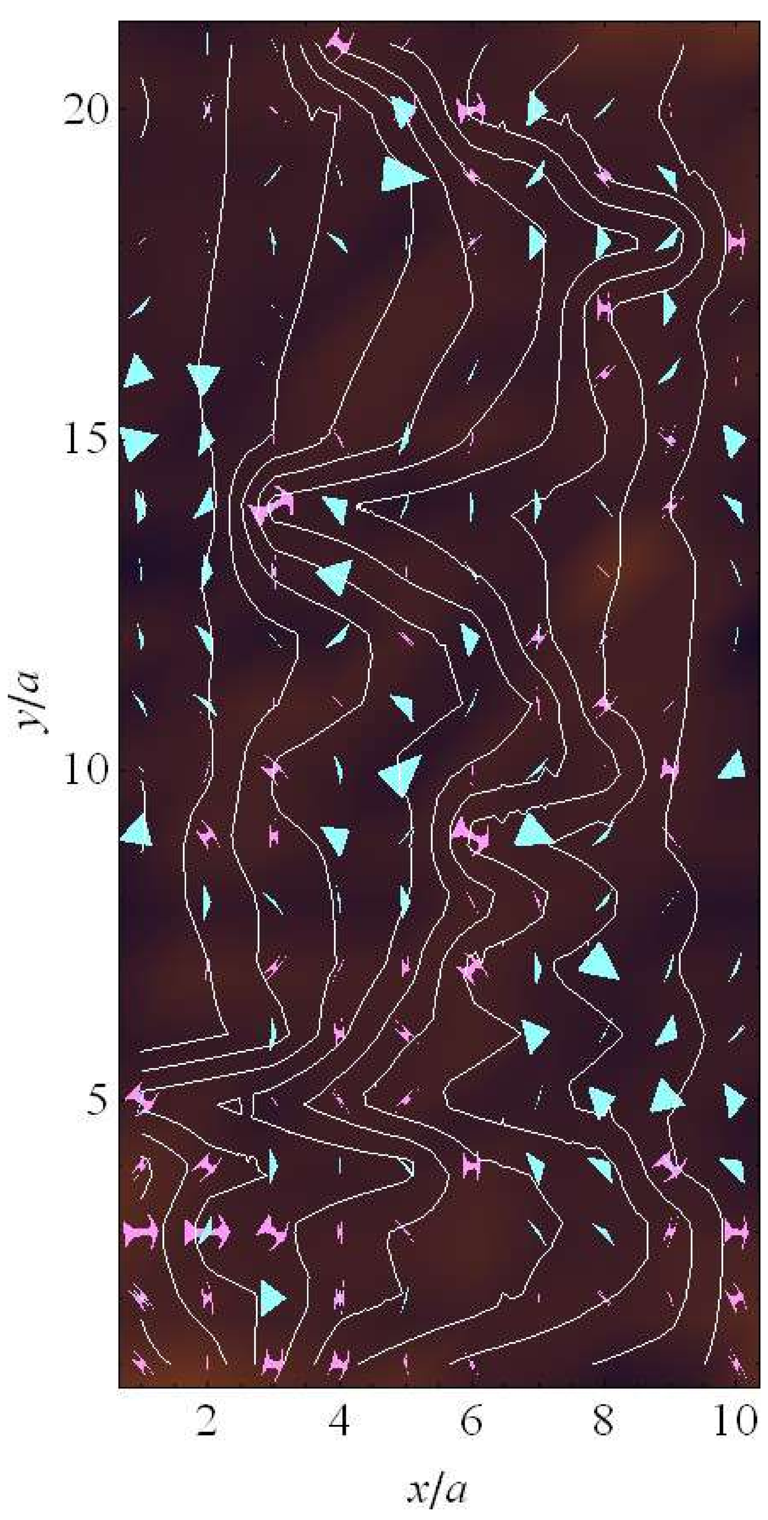
Fig. 4. Magnetoresistance peak



(a) At low magnetic fields the sample is entirely superconducting



(b) Both normal and superconducting current



(c) At high magnetic field the system is in the normal state